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ORIGINAL PAPER



A study of academic achievement in mathematics after the transition from primary to secondary education

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Abstract

A successful transition from primary to secondary school is central to student confidence and the sustainment of student interest and passion for learning. The literature indicates that difficult transitions can result in decreased levels of motivation, negative attitudes towards school, decreased levels of confidence and disengagement particularly in relation to mathematics. This study investigated student performance in mathematics after the transition from primary to secondary education in Ireland. It comes in the aftermath of major educational reform in mathematics in Ireland at both primary and secondary level and is the first Irish study to examine the effect of the transition on mathematical achievement. Academic achievement in mathematics was measured using a standardised test at the end of the final year of primary school and the end of first year of secondary education. Progress in mathematics was measured over the transition by comparing these two test results for 249 students. On average, students' raw scores decreased by 7% from sixth class (final year of primary school) to the end of first year of secondary education despite an additional year of instruction and extensive overlap of both syllabi. The results showed statistically significant losses in each strand area and in each process skill. This academic transition is not unique to Ireland and the findings from this research study will be of interest to the mathematics education community internationally since it extends the evidence base for studies in school transition.

Keywords Primary-secondary transfer · Transition in mathematics · Factors affecting success in transition · Mathematical achievement

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Introduction

Successful academic performance during adolescence is a key predictor of lifetime achievement, including occupational and social success. (Serbin et al. 2013, p. 1331)

Transition to secondary education, once the preserve of a few, is now seen as an automatic rite of passage in Ireland and it is a transition experienced by over 50,000 students each year (Smyth et al. 2004). It is a momentous period of change for students and one of the greatest challenges experienced by students in their school career (Prendergast et al. 2019). Researchers have recognised the transition from primary to secondary education to be a major milestone in the educational journey of the student and much has been reported on this transition both nationally (Irish National Teachers' Organisation 2008; O'Brien 2001; Smyth et al. 2004) and internationally in recent years (Anderson et al. 2000; Doyé and Hurrell 1997; Midgley et al. 1989; van Rens et al. 2017). Indeed, international experience shows the transfer to post-primary school is often not successful for many students creating both short-term and long-term consequences (van Rens et al. 2017). Galton et al. (2000) observed, in their UK study, that unsuccessful transition to secondary school has implications both socially and academically, and often the disengagement with education that follows from an unsuccessful transition will continue into adult life. Galton et al. (2000) also showed that transition can be a negative experience characterised by academic decline, decline in self-esteem and development of a dislike towards certain subjects. There is an absence of research globally on the academic transition that is taking place at this time (Galton et al. 2003). In this paper, the authors focus on the academic transition in mathematics in Irish schools, measuring student performance for a specific cohort of students using a representative national sample, and identify and discuss issues that impact on this transition. Getting the academic transition in mathematics from primary to secondary education right is very challenging and extremely important for the future education of the nation's children; children's psychological well-being; their academic future; not forgetting the national economic well-being of the country and issues of social justice and participation.

Transition and mathematics—the literature

In a New Zealand study, Bicknell and Hunter (2012) found that the transition process is central to student confidence and the sustainment of student interest and passion for learning as students pass from primary to secondary school. The literature shows us that difficult transitions can result in decreased levels of motivation, negative attitudes towards school, decreased levels of confidence and disengagement particularly in relation to mathematics (McGee et al. 2003).

if you are on the scrapheap by the age of 11, you are likely to remain there.

(Vorderman et al. 2011, p. 5)

Students who achieve at an early stage continue to succeed. In the UK, 94% of those who exceed the Statutory Assessment Test (SAT) target in the Key Stage 2 National Test (typically 10–11 years of age) will pass their General Certificate of Secondary Education (GCSE) mathematics (typically 15–16 years of age). 90% of those who do not attain the SAT target in the Key Stage 2 National Test at the end of primary school will fail their GCSE mathematics (Vorderman et al. 2011). The gap between the highest and lowest achieving students widens as they advance through secondary schooling and by the time a student turns 16, there already exists a 10-year difference in mathematics achievement between the highest and lowest achieving students (Brown and Armstrong 1982). Bicknell and Hunter (2012) studied the experiences of year six students (aged between 11 and 12) in New Zealand making the transition and they focussed on these students' experience of mathematics. They found that students' loss of motivation to engage in mathematics might be a result of their initial experiences of secondary school characterised by academic pressures and discontinuity of learning context. In their Australian study featuring 194 students spanning both middle school and high school, Martin et al. (2015) highlighted that aspirations in mathematics and engagement in the subject decline over time. Research in Ireland has highlighted that teachers feel there is a lack of fluidity in the transition process from primary to secondary education (Prendergast et al. 2016). As the New Zealand study found, orientation support such as school visits, information and teachers focussing on the skills needed for the transition are vital for academic success in mathematics (Bicknell and Hunter 2012; Bicknell and Riley 2012). However, while Neild et al. (2008) show using US data that ninth grade outcomes are major predictors of dropout they also argue that the transition to high school is a time where a student's educational trajectory can be reshaped. If this is true, the first year of secondary education not only establishes a base for mathematical advancement but also more importantly represents a major opportunity for educators.

Studies on mathematics achievement over the transition

Several studies have been carried out to assess the implications of the transition process (Ashton 2008; Bloyce and Frederickson 2012; Chedzoy and Burden 2005; Lucey and Reay 2000) but very few have concentrated on the academic transition (Carmichael 2015; Cox and Kennedy 2008; Galton et al. 2003; Smyth et al. 2004).

Despite strong interest internationally in transition studies, there is a gap in the international research on education transitions specifically in relation to studies that quantify the impact of the transition on mathematics achievement, and it is suggested that this is attributable to difficulties associated with finding valid measures of mathematical achievement that reflect the first-year post-primary curriculum (Carmichael 2015). In an Australian study involving 3345 students, Carmichael (2015) showed that the transition to secondary school negatively affects the mathematics performance of students. However, this decrease in performance is not witnessed when students change from one primary school to another. Carmichael suggests this may be due to discontinuity in learning between primary and secondary schooling.

In England, the ORACLE (Observation Research and Classroom Learning Evaluation) study of transfer from 1975 to 1980 discovered that almost 45% of boys and 35% of girls scored less at the end of their first academic year at secondary school than the final term of primary school in the exact same standardised mathematics skills test. The replication of this study two decades later still found 34% of students scoring less on the standardised mathematics tests after a year in secondary school than they did in the last term of primary (Galton et al. 2000). This academic decline is accompanied by a decline in motivation and enthusiasm for school (Galton et al. 1999). In mathematics, there was also a decline in work rate with pupil engagement in the work set by the teacher falling from 61 to 50% following transfer to secondary school (Galton et al. 2000). It is important to note that the second study showed the same results despite extensive educational reform in the intervening years with the introduction of the National Curriculum. Galton et al. (1999) suggest that schools should concentrate on measures to guarantee academic progress and sustained commitment to learning. While one of the objectives of the National Curriculum was to ensure curriculum continuity, problems remain with curriculum continuity at the time of transition. Galton et al. (1999) suggest that the differences in teaching approaches between primary and secondary education need to be investigated and suggests that secondary teachers are still advocating a 'fresh start' approach despite the evidence to suggest that this is not an effective strategy.

In an Irish study, Smyth et al. (2004) found that the majority of students do not make progress in computation between the September and May of first year in post-primary school (lower secondary education). Only 10% of students showed a significant improvement in computation. Smyth found that students who had low computation scores in September made the most progress. She also found that parental involvement correlates positively with progress in computation scores. Smyth suggests that the change in teaching styles between sixth class and first year could be a possible cause for the failure of students to make academic progress in mathematics in first year. Students were more likely to find mathematics in secondary education to be more difficult than primary level if there was a mismatch between teaching methods across the transition. 75% of students reported that subjects were taught in a different way in primary school than in secondary schools. Many students felt there was a 'mismatch' between the mathematics taught in both schools and those that feel there was a mismatch take more time to settle into first year. Only approximately 50% of mathematics teachers considered the primary school syllabus was a good foundation for mathematics in first year.

The Students' Transition from Primary to Secondary Schooling study was an exploratory study undertaken in New Zealand to investigate the impact of transition on student achievement as students move from primary to secondary schooling (Cox and Kennedy 2008). Students in this study were assessed in the following content areas in mathematics: geometric operations, number operations and measurement (Cox and Kennedy 2008). Student achievement from Phase 1 (students were completing their last weeks of primary or intermediate school) to Phase 2 (students were completing their last weeks of term one in their secondary school) showed a decline, possibly attributed to the summer break (Cox and Kennedy 2008). By Phase 3 (students were completing their last weeks of term four, at end of year 9), the majority

of students were achieving at or above the level achieved in Phase 1. Average mathematics scores declined between Phase 3 and Phase 4 (students were completing their last weeks of Term 1 of year 10) even though there was not a change of school (Cox and Kennedy 2008). The decline was not as dramatic as the decline between Phase 1 and Phase 2 (Cox and Kennedy 2008).

These studies, along with the composite theoretical framework, were used to guide the research study with a view to ultimately improving both first year students experience of school mathematics, and professional practice in school mathematics teaching.

The Irish context

The study was conducted against a backdrop of major curriculum reform in mathematics in Ireland in recent years, and this reform has included changes across the transition. A new mathematics curriculum was implemented to address various shortcomings in the post-primary (secondary) school curriculum. These included issues such as the low percentage of students pursuing higher level leaving certificate mathematics—the leaving certificate examination is the high stakes final examination in the Irish post-primary education system, and mathematics can be pursued at higher level, ordinary level or foundation level for this exam. Other concerns were the poor standard of answering in state examinations; disappointing performances in international assessments; and low levels of mathematical knowledge witnessed in third level (NCCA 2005). Importantly for this study, the discontinuity between primary and post-primary or secondary mathematics was identified as an area of concern.

The new mathematics curriculum represents a move away from procedural routine mathematics and rote learning towards the development of a deeper understanding of mathematical concepts (Cosgrove et al. 2012). The new revised curriculum organises the syllabus content in five strands: Statistics and Probability, Geometry and Trigonometry, Number, Algebra and Functions. Despite the introduction of the new curriculum which was fully implemented by 2012, Ireland as a nation, still lags behind in its mathematics education in both TIMSS and PISA testing compared to its international counterparts (Clerkin et al. 2016; Shiel et al. 2015). In Ireland, it has been shown that transition is a time of excitement but also stress for first year students (students in year one of their secondary education in Ireland) (O'Brien 2001). A later study by Smyth et al. (2004) discussed below, reported significant student underperformance in computation after the transition in question. It is not surprising that efforts in Ireland to support transition followed the general trend and have concentrated on the social and the psychological ramifications of transition. Despite targeted efforts to improve matters in the context of the recent mathematics education reforms, recent research in Ireland focussed on teachers, has identified continuity across the transition from primary to post-primary (secondary) education as an significant concern (Prendergast et al. 2016).

The academic progression in mathematics of students during the critical first year of secondary education in Ireland was not explored in detail until this study.

This paper is based on an extensive PhD study that addresses this gap, and helps to explain, challenge and extend existing knowledge on transition.

Key factors affecting success in transition

The literature reviewed identified factors that affect success in the academic transition from primary to post-primary (secondary) education. The authors highlight three factors here for discussion because they have a significant negative impact on the transition in Ireland: academic discontinuity, the ‘Fresh start’ approach, and instruction time. These same factors emerge later in the study because they have a significant bearing on its outcomes and recommendations for improvements.

Discontinuity

The negative impact of academic discontinuity has been flagged in Ireland and students who feel this discontinuity take longer to settle into secondary school (NCCA 2004). Cooperation between primary and secondary schools is necessary for successful transition and is also important to parents (NCCA 2004). Subject teachers need to take into account not only the curriculum at primary level, but also the methodologies used to deliver the curriculum and the strengths and weaknesses of the individual making the transfer. Gorwood (1991) looked at transition in the UK following the introduction of the National Curriculum and found little contact between primary and secondary teachers. In 2004, Smyth et al. (2004) reported that only half of secondary teachers in Ireland are familiar with the primary curriculum. 12 years later, Prendergast et al. (2016) found very similar results with 56% of primary sixth class teachers (sixth class is the final year of 8 years of primary education) and 49% of secondary teachers reported being either highly or slightly unfamiliar with each other’s syllabi. 73% of final year primary teachers and 77% of first year secondary mathematics teachers reported being unfamiliar with the teaching methodologies employed in the teaching of mathematics in secondary and primary school, respectively (Prendergast et al. 2016). Failure to recognise what and how students learn in primary school mathematics can lead to students becoming confused and believing it to be difficult (NCCA 2005).

‘Fresh start’ approach

Academic discontinuity is evident in the ‘fresh start’ approach where secondary teachers prefer to start again and re-teach much of the material already covered in fifth and sixth class in primary school. Nearly a third of students in Ireland say that several first year subjects are a repetition of what had already been learned in primary school (NCCA 2005). Repetition of learning has also been reported as a factor impeding transitional success in New Zealand (Bicknell et al. 2009). For the mathematical transition of exceptionally able students, this approach is especially detrimental as it negates their identification with primary school and the learning that

occurred at primary level (Bicknell and Riley 2012). Indeed, the distrust inherent in the ‘fresh start’ approach impedes smooth transition and halts academic progress for students of all ability. Galton et al. (2000) warn that this approach is likely to lead to boredom in students who already know the material, and on the other hand the speed of the revision classes could be too much for weaker students. The repetition of learning can lead to confusion or disengagement with mathematics (Bicknell and Hunter 2012). Different methods of teaching the same topics between primary and secondary school is also likely to lead to confusion (Galton et al. 1999). Mathematics learning must be progressive and repetition of learning and assessment in first year secondary school does not promote a positive attitude to the subject (Bicknell and Riley 2012). Research in the UK has shown that students entering secondary education need to be challenged to build on progress made in sixth class and curriculum interest and continuity are key factors in successful transition (Evangelou et al. 2008).

Instruction time

The link between instruction time and academic achievement was originally highlighted by Carroll in 1963 (OECD 2010) and since then, the significance of instruction for student performance has been widely investigated internationally (Clark and Linn 2003; Lavy 2015; OECD 2010; Smith 2000). The Third International Mathematics and Science Study (TIMSS) and other international studies have shown a positive correlation between academic performance and instruction time (Smith 2000). Research from the 2003 cycle of the Programme for International Students Assessment (PISA) has shown that there is a strong correlation between mean performance in mathematics and total mathematics instruction time (OECD 2010). Using US data, Smith (2000) concluded that the effect of instruction time can explain from 10 to 40% of the difference in student performance.

In Ireland, it is recommended that students in sixth class spend 50 min on mathematics per day (McCoy et al. 2012). On the other hand, a first year secondary student in Ireland is more likely to spend 35 min per day on mathematics (Smyth et al. 2004). Students suffer an immediate reduction in mathematics instruction time after they enter first year of secondary education, 30% per day and 36% over the academic year. Furthermore, the mean number of weeks per academic year across Organisation for Economic Co-operation and Development (OECD) countries is 36–40 weeks (OECD 2010). However, Ireland is considerably below this norm with 33 weeks and this is significant since performance is positively correlated to the length of the school year (OECD 2010).

Theoretical frameworks

The composite framework underpinning this study takes elements of the following models: Rite of Passage (Clark and Lovric 2009), Communities of Practice (Wenger 2000) and Schlossberg's Theory on Adult Transitions (Schlossberg 1981). This composite framework underpinned the methodology, analysis and recommendations.

Even though the Rite of Passage framework developed by Clark and Lovric (2009) has been applied to first year university students, it examines transition over a two year period, emphasising that adapting to transition takes time (Clark and Lovric 2009). It is also a model designed to understand transition in mathematics and the lengthy period of analysis proposed by the Rite of Passage model (Clark and Lovric 2009) allows for losses due to the absence of mathematical activity in the summer between the end of primary school and the start of post-primary school. In an effort to increase the validity of findings, their approach directed the timing of academic testing that took place in this study. These two time periods represent transition phases namely, the incorporation phase and the adjustment section of culture shock of the Rite of Passage model where students have gained the ability to cope with the new situation. However, the academic data does question whether students have reached the adaptation stage of the culture shock. This culture shock phase is exacerbated by the differences in instruction time allocated to mathematics in primary and post-primary school in Ireland.

The Communities of Practice (Wenger 2000) framework provides a sociocultural backdrop allowing for focus on the importance of relationships between members of the individual's community and the reconstruction of identity. This Community of Practice model is particularly suitable for this research study as it views learning as a social endeavour within a community that requires the collaboration of parents, children and teachers. It encourages students, teachers and parents to take an active role in planning learning activities. In addition, parents and teachers not only teach but also learn from their involvement with the child (Rogoff et al. 2003). If we view mathematical learning through the community of practice (Wenger 1998) lens, we can see that collaboration of parents, students and teachers is necessary for transitional success. The strength of these relationships within this community is what leads to student engagement and mastery. This model highlights that the lack of collaboration between primary and post-primary teachers and the absence of significant parental involvement in mathematics education of first year students are possible stumbling blocks in a student moving from the periphery to the centre of the community as competence increases. Indeed, it questions whether it is possible for the individual to move to the centre of the community given the absence of collaboration.

Schlossberg's Theory on Adult Transitions (Schlossberg 1981) stresses that the experience of transition is unique to each student but all transition incorporates stress and is dependent of the individual's resources and deficits. Echoing the Communities of Practice (Wenger 2000) framework, it emphasises the importance of support systems in successful transitions. It also recognises that the characteristics of the individual such as sex and sex role identification, and psychosocial

competence and age impact greatly on successful transition. Schlossberg's Theory on Adult Transitions (Schlossberg 1981) provided the following constituents of the composite framework:

- Adaptation to change relies on the individual's balance of resources to deficits at the time of transition but invariably involves a degree of stress for all students.
- The transition environment (interpersonal support systems, institutional support and the physical setting) can provide support to the student.
- The characteristics of the individual (internal locus of control, sense of responsibility, moderately favourable self-evaluation, sense of optimism, ability to plan for success, ability for enjoying success and ability to cope with failure, sex (and sex role identification, etc.) all impact an individual's success in managing transition.

Schlossberg (1981) enables us to identify the role change that students experience in first year. While the transition to post-primary school is expected and has a definite duration, it does involve a role change that causes stress and the stress is more pronounced depending on gender and gender identification. It is also coupled with the biological and physiological changes associated with age. Schlossberg stresses that most transitions involve both positive and negative emotions. Adaptation to transition is exacerbated by lack of interpersonal support. This highlights the need for greater parental involvement in the mathematical transition of students from primary to post-primary education.

Method

Research problem and questions

The study investigated academic progress during first year of post-primary school. After reviewing the literature and designing the composite framework, the following research questions emerged, which provided the direction for this study in the context of the introduction of the new mathematics curriculum in 2010:

- What progress, if any, do Irish students make in mathematics in first year of post-primary school?
- How do students fare in the individual strand areas; number; measures; shape and space; algebra and data; and in the process skills of concepts and facts, computation and word problems; that comprise the first year mathematics curriculum?
- What implications can we draw from the first-year data in mathematics?

Research design

Careful consideration was given at the design stage as to how to measure progress in mathematics as intended, and what instruments would be used. The use of a custom self-constructed assessment instrument was ruled out in favour of

Table 1 STEN scores

STEN score	What does the STEN score mean?	Proportion of children with this score
8–10	“Well above average”	1/6
7	“High average”	1/6
5–6	“Average”	1/3
4	“Low average”	1/6
1–3	“Well below average”	1/6

two existing standardised tests as detailed below. While significant preliminary work was done to confirm that the choice was a good match for this study e.g. the tests were already standardised for the same population of Irish students, the mathematics was appropriate and matched the expected outcomes of the current curriculum. Further, we were satisfied that appropriate statistical analyses would yield valid data and findings. Using these test instruments the researchers were able to set up a pre- and post-test scenario and match pre scores to post scores maintaining confidentiality and anonymity by working with school principals, teachers and students and various other stakeholders as required.

The two main standardised assessment instruments purposely designed for use within the Irish primary school system, and commercially available, are the SIGMA-T and Drumcondra Primary Mathematics Test—Revised. Both tests were standardised using a population of relevant students in Ireland and were designed to measure student knowledge of the curriculum. Given that standardised achievement scores and prior grades are the strongest predictors of high school grade point average (GPA) (Casillas et al. 2012), the authors used an appropriate standardised sixth class (primary school) test to assess student progress across the transition.

The Level 5 SIGMA-T contains 119 items to assess student achievement in the following five areas: number, measurement, geometry, elementary algebra and data and statistics. These questions are mostly based on the mathematics curriculum from the last two years of primary school and require students to perform several mathematical procedures and solve word problems relating to the content studied (Wall and Burke 2015). The Level 5 SIGMA-T provides a raw score, standard score, percentile rank and STEN score. The raw score relates to the number of questions answered correctly from a total of 119 questions in the SIGMA-T test. Raw scores can then be converted into standard scores, percentiles and STEN scores. A STEN score (Table 1) is a score from 1 to 10 that compares a student’s result to that of the standardised sample (NCCA 2008).

The percentile rank is useful in comparing students in more detail than the STEN score and compares student results to that of the standardisation sample, at the end of sixth class. If a student obtains a percentile rank of 64, it means that the student has performed as well as, or better than, 64% of students who formed the standardisation sample at the end of sixth class. The percentiles assigned to all first year data in this study are based on a sixth class standardised sample.

The Drumcondra Primary Mathematics Test—Revised is a standardised mathematics assessment test and was developed in 1997 and revised in 2005. More than 16,000 pupils were used in the development of the norms for each level of the test. Level 6 of the test is used for students in sixth class. The test provides a raw score, standard score, STEN score and percentile rank as well as scores on the strand areas and process skills. This was possible as the authors of the SIGMA-T compared the standard scores of 256 students who sat both the Drumcondra Primary Mathematics Test- Revised (Levels 5 and 6) and the SIGMA-T (Level 5) and the correlation was found to be 0.854.

The target population was first year students in the Republic of Ireland commencing secondary education in September 2015. The sampling design used for this study was modelled on the sampling design used for PISA assessment (OECD 2014). The sampling frame was the entire set of 723 post-primary schools in Ireland and this accounted for 367,178 students, which approximated to 61,196 first year students. Ethical approval for this study was granted by the appropriate ethics committee at the University of Limerick (Code: 2015_09_01_S&E). The first stage of the sample design involved stratifying the list of schools into the four distinct school types, namely: secondary, vocational, community and comprehensive.¹ It was decided to use these categories as data on the number of schools and students attending each school are readily available for each stratum. Separate school sampling sub-frames were composed for each school type and 14 schools were sampled using probability proportional to size systematic sampling. A simple random sample of first year mathematics classes in a chosen school was used to select a class and all students from the selected class were included in the sample. These students had completed a competency test, SIGMA-T Level 5 or Drumcondra Primary Mathematics Test—Revised Level 6 at the end of primary school. The SIGMA-T Level 5 test was re-distributed a year later to measure progress in academic achievement in May 2016.

The final sample size was 323 students. Due to absenteeism, 301 students sat the SIGMA-T at the end of first year. It was possible to obtain the sixth-class results for 249 of these students by contacting the primary school they attended. This was a very onerous but necessary task for the researcher and involved a major commitment of her personal resources over a long period as 109 primary schools were involved. It was not possible to obtain sixth-class data for 52 students due to non-cooperation or absence of records.

To determine the effects of the transition from primary to secondary education on students' achievement, an analysis of students' pre- and post-test scores was carried out. The purpose of the comparison was to assess student progress in mathematics during the first year in secondary education. The authors categorised student data into three groups:

¹ Secondary schools are privately owned and managed. Vocational schools are governed by the state through Education and Training Boards (ETBs), while Boards of Management manage community and comprehensive schools.

- Students who completed the SIGMA-T standardised mathematics test in sixth class and also the SIGMA-T standardised mathematics test in first year (Student Group A),
- Students who completed the Drumcondra standardised mathematics test in sixth class and the SIGMA-T standardised mathematics test in first year (Student Group B),
- All students who completed either the Drumcondra or SIGMA-T standardised mathematics test in sixth class and the SIGMA-T standardised mathematics test in first year (Student Group C).

All the data were collected and imported into SPSS for quantitative analysis. A paired t -test was employed on each of the three groups to determine whether there was a statistically significant mean difference in the results obtained at the end of sixth class and the end of first year. The authors chose the paired t -test as the data were approximately normal and the paired t -test is robust enough to deal with departures from normality (Marshall 2015) once the sample size is large enough ($n > 30$ or 40) (Ghasemi and Zahediasl 2012).

Curriculum map

A curriculum map was constructed for the purposes of checking the extent to which the learning outcomes of the sixth class (primary school) mathematics curriculum corresponded to the learning outcomes of the first year *Common Introductory Course* (post-primary/lower secondary school). The primary mathematics curriculum in Ireland is bridged to the Junior Cycle (year 1–3 of post-primary school) mathematics curriculum through the *Common Introductory Course*. The *Common Introductory Course* introduced as part of the revised curriculum and followed by first year students in secondary education, aims to build on the mathematics experiences of students in fifth and sixth class of primary school. This analysis showed that 82% of the learning outcomes of the sixth-class mathematics curriculum are repeated in the first year *Common Introductory Course*. This very high level of correspondence between curricula reinforced our confidence in the approach taken in this study and the instruments used.

Results

In this section the authors present an overall summary of statistical results followed by a more detailed analysis focussed on each student group A, B and C.

Summary of results

The academic results of this study indicate that academic transition in mathematics is problematic for many students as they proceed from primary to post-primary education in Ireland and suggests that students are underperforming in mathematics

Table 2 Raw score paired-samples statistics

	Mean	N	Std. deviation	Std. error mean
Pair 1				
Raw score 1	76.245	163	20.2951	1.5896
Raw score 2	68.374	163	21.3689	1.6737

during this phase of their education. This study found statistically significant decreases of 7.87 in raw score ($n = 163$) and of 0.78 in STEN ($n = 176$), between the end of sixth class and the end of first year, for the students who sat the SIGMA-T on both occasions. For the 249 students who sat either the SIGMA-T or Drumcondra in sixth class and the SIGMA-T at the end of first year, the decrease in STEN score was 0.77 and the decrease in percentile was 8.18. All decreases were statistically significant. In a comparison of STEN results for 249 students, 59.04% of students regressed, 6.43% of students showed an increased STEN result and 34.54% of students recorded no change in STEN. Since the STEN scores assigned to all first year data are based on a sixth class standardised sample, this means that the changes reported in this study are conservatively estimated and the losses incurred in first year are more pronounced. It was possible to compare results by strand area for 87 students and there was a statistically significant decrease across each of the five strands. Shape and Space results declined by 12.46%, followed by Data which declined by 11.55%, Algebra declined by 6.18%, Measures declined by 5.39% and Number declined by 3.82%. The greatest decline related to Shape and Space results and this has been repeatedly highlighted as an area of concern in PISA 2003 and PISA 2012 results (Perkins and Shiel 2016). It was possible to compare results by process skill for 87 students and there was a statistically significant decrease across each of the 3 process skills. The greatest decline was in computation where this skill worsened by 8.75%, followed by word problems which worsened by 6.91% and concepts and facts which worsened by 5.77%.

Student Group A

Incomplete data from sixth class allowed comparison of raw scores for 163 out of 176 students. These students completed the SIGMA-T standardised mathematics test in sixth class and the SIGMA-T standardised mathematics test again at the end of first year of secondary education. The raw score relates to the number of questions answered correctly from a total of 119 questions. A paired-samples *t*-test was conducted to evaluate the impact of the first year mathematics course on students' raw scores on the SIGMA-T test. There was a statistically significant decrease in scores from Time 1 to Time 2 (Table 2). These results question the effectiveness of the Common Introductory Course followed by first year students and are indicative of the discontinuity and fresh start approach, which are known to hamper transitional success.

A Pearson product-moment correlation coefficient was computed to assess the relationship between raw score 1 and raw score 2. The data show a positive

Table 3 Percentile paired-samples statistics

	Mean	<i>N</i>	Std. deviation	Std. error mean
Pair 1				
Percentile 1	64.806	72	26.7201	3.1490
Percentile 2	52.806	72	28.3627	3.3426

correlation between raw score 1 and raw score 2, $r=0.87$, $n=163$, $p<0.005$. The mean decrease in raw scores was 7.87 with a 95% confidence interval ranging from 6.20 to 9.54. The eta squared statistic (0.35) was used to measure effect size or the size of the difference between both sets of data. This represents a large effect size which is an effect that is so large and consistent enough that it is sometimes possible to see it with the naked eye (Coe 2002). On average, students' raw scores decreased from 76 questions correct from total of 119 to 68 questions correct from a total of 119 between the end of sixth class and the end of first year of secondary education.

Student Group B

73 students in the overall sample completed the Drumcondra standardised test in sixth class and the SIGMA-T standardised test at the end of first year. As the Drumcondra Primary Mathematics Test- Revised (Levels 5 and 6) and the SIGMA-T (Level 5) have a strong positive correlation of 0.854, it was possible to compare both tests for these 73 students. A paired-samples t -test was conducted to evaluate the impact of the first year mathematics course on students' percentile scores. There was a statistically significant decrease in percentiles from Time 1 to Time 2 (Table 3). The eta squared statistic (0.37) indicated a large effect size. The results highlight that students fail to show mathematical advancement during the course of first year.

A Pearson product-moment correlation coefficient was computed to assess the relationship between percentile 1 and percentile 2. The data show a positive correlation between percentile 1 and percentile 2, $r=0.84$, $n=72$, $p<0.005$.

Student Group C

Student Group C is formed by combining Student Group A and B. This accounts for 249 students who completed either the Drumcondra or SIGMA-T standardised mathematics test in sixth class and the SIGMA-T standardised mathematics test in first year. The results from this overall group show a decline in student mastery, which is perhaps partly attributable to the weakening of the strength of the relationships within this community of learning as students pass from primary to post-primary school. One of these relationships involves the knowledge of respective curricula and teaching methodologies between sixth class and first year teachers (Prendergast et al. 2016). The results also suggest a level of confusion which may be due to the different methods of teaching the same topics between primary and secondary school (Galton et al. 1999). There is a strong positive correlation between student performance on both tests ($r=0.88$ for STEN and $r=0.73$ for Percentile). A

Table 4 STEN and percentile paired-samples statistics

	Mean	<i>N</i>	Std. deviation	Std. error mean
Pair 1				
STEN score 1	6.618	249	1.9227	0.1218
STEN score 2	5.847	249	1.9158	0.1214
Pair 2				
Percentile 1	61.916	249	30.3578	1.9238
Percentile 2	53.739	249	28.9468	1.8344

paired-samples *t*-test was conducted to evaluate the impact of the first year mathematics course on students' STEN and Percentile scores. There was a statistically significant decrease in STEN and Percentile scores from Time 1 to Time 2 (Table 4). The mean decrease in STEN scores was 0.77 with a 95% confidence interval ranging from 0.65 to 0.89. The eta squared statistic (0.40) indicated a large effect size. The losses recorded in each of the student groups are more pronounced than comparable studies (Cox and Kennedy 2008; Galton et al. 2000). The mean decrease in percentile scores was 8.18 with a 95% confidence interval ranging from 5.46 to 10.89. The eta squared statistic (0.12) indicated a large effect size.

A Pearson product-moment correlation coefficient was computed to assess the relationship between STEN score 1 and STEN score 2. The data show a positive correlation between STEN score 1 and STEN score 2, $r=0.88$, $n=249$, $p<0.005$. A Pearson product-moment correlation coefficient was computed to assess the relationship between percentile 1 and percentile 2. The data show a positive correlation between percentile 1 and percentile 2, $r=0.73$, $n=249$, $p<0.005$. The data indicate negative outcomes for students across all the statistical tests used.

Discussion

Research questions revisited

The findings are surprising and worrying on several fronts from the perspective of the researchers who are experienced professional mathematics teachers and mathematics teacher educators. Using the methodology described earlier in the paper, the data show a statistically significant decline in student performance in mathematics at the end of first year post-primary school. This decline is greater than that reported in other studies e.g. Galton et al. (2000). For example, for student group A, where it was possible to compare raw scores at the end of sixth class with raw scores at the end of first year of post-primary, 81% of students dis-improved. This is surprising given the reform emphasis in mathematics and the bridging strategy employed based on a Common Introductory Course (CIC) that was designed specifically to ease the transition in mathematics.

How did students fare in the individual strand areas; Number; Measures; Shape and Space; Algebra and Data; and in the process skills of Concepts and Facts,

Computation and Word Problems; that comprise the first-year mathematics curriculum? Research Question 2 investigated the performance of students in all strand areas in order to develop a more detailed profile of students' performance including their command of important process skills. This study recorded statistically significant decreases in all strand areas and in each process skill. Clearly, the TIMSS results for Ireland in 2015 (Clerkin et al. 2016) suggesting the reforms have been successful only at primary level, was an early warning that much more needed to be done at post-primary level.

What implications can we draw from the first-year data in mathematics? We are surprised to find that the sample as whole exhibits a significant decline in mathematics performance, and worried because this is so despite unprecedented attention and investment in a new post-primary mathematics curriculum and teacher professional development. This was unexpected as we had followed the Rite of Passage model (Clark and Lovric 2009) ensuring our testing took place at the end of first year which allowed for losses over the summer months and a lengthy settling in period. A previous Irish study (Smyth et al. 2004) pointed to issues with computation in the transition but clearly there are wider concerns as this study indicates poor performance across all strands of the mathematics curriculum.

The influence of contextual factors

These poor results must be taken in context, and in this case they are mitigated somewhat by the prevailing circumstances at the time and immediately prior to it when the new mathematics curriculum was implemented on a phased basis and was 'bedding in', and the government was engaged in a major programme to upskill out of field of teachers of mathematics. There is also the matter of the sociocultural milieu in education and its impact on the transition. Historically in Ireland, school education is examinations oriented with high stakes State examinations at the end of schooling. This emphasis and its impact on professional practice in mathematics teaching has led to a narrow exam-oriented pedagogy in mathematics that is difficult to replace during reform of the curriculum. An additional layer of difficulty is added by circumstances in teacher education since there is complete separation between the teacher education for primary and post-primary teachers. The authors have attempted to understand and rationalise these issues as they impact on the academic transition in mathematics in Ireland by resorting to Bernstein's work. Bernstein's theory on classification and framing (Bernstein 2000) offers another perspective on examination of the results. Post-primary schools in Ireland are typically associated with stronger classification and stronger framing than primary schools, given for example, the multiplicity of teachers and subjects as well as the focus on examinations. The very nature of instruction in post-primary school, students going from a single teacher to multiple teachers in post-primary school represents strong subject classification (Bernstein 2000) and lessens the opportunities for integration. In addition, the lack of collaboration between primary and post-primary teachers points to strong classification and strong framing (Bernstein 2000) The decreased instruction time and the focus on exam pressures at secondary level points to strong framing

which limits the teacher's autonomy to choose their teaching and learning methods. The academic decline may be correlated to the classification/ boundaries in operation in a school environment and the framing/ power teachers and students have on practice within this environment. How student knowledge is formed is a function of this classification and framing. In addition, the classification and framing of knowledge moulds identity and consciousness through the distribution and re-contextualisation of the knowledge (Wheelahan 2005). The academic decline highlighted by the results may be indicative of the differences in the levels of control a first-year mathematics teacher and a sixth-class mathematics teacher has in relation to pedagogy, assessment and curriculum design.

Nevertheless, the results are a cause for concern. The results highlight an opportunity cost for students as they are failing to reach their full potential in mathematics in first year. This underperformance in first year has a knock-on effect in the remaining two years of Junior Cycle (lower secondary) school. This leads to students trying to make up lost ground in their subsequent two years of Junior Cycle mathematics and militates against more students achieving higher grades even for students who make up lost ground. While the national strategy target is 60% of students sitting the Junior Certificate higher level mathematics exam by 2020 (Department of Education and Skills 2011) has been achieved, increased numbers of students sitting higher level mathematics is not a cause for celebration when significant improvements in mathematics have not been recorded by PISA and TIMSS in relation to post-primary schools (Clerkin et al. 2016; Perkins and Shiel 2016).

Contributory factors related to underperformance in mathematics

This study points to the mathematical transition from primary to secondary education as a significant contributory factor in Irish student's underperformance in mathematics in Junior Cycle (lower secondary education). A number of factors such as instruction time, collaboration of stakeholders and the Common Introductory Course are important considerations in understanding how best to improve the transition process in mathematics. While The National Strategy to Improve Literacy and Numeracy among Children and Young people 2011–2020, and PISA and TIMSS testing highlight the importance of the transition from primary to secondary education, they do not specifically examine the transition. TIMSS testing in second year and PISA testing for students aged 15 do not show or examine the impact of transition on student mathematical advancement. This study addresses this gap and provides evidence of a significant decline in mathematical achievement between sixth class and first year in Irish schools.

Instruction time in school mathematics

The difference in instruction time between sixth class and first year of secondary school may account in part for the TIMSS 2015 results which have shown significant improvements in fourth class results (primary school) but no real improvements in second year (post-primary/lower secondary) achievement data since 1995. In

addition, PISA 2015 results show Irish students are not among the high performing mathematics countries and no real improvement in achievement has been recorded despite the introduction of the new post-primary mathematics curriculum. To ensure continuity, the issue of instruction time may have to be revisited. Perhaps it would be prudent to, at least, match that of sixth class. In addition, it is important to recognise that at secondary school, either the teacher or the students must move to a different classroom and this disruption further affects the quantity and the quality of the instruction time. Improving performance is not simply about increasing the amount of instruction time available but about maximising instruction time to ensure students are engaged in tasks which provide a challenge and yet allow them to experience success (Aronson et al. 1999). The decreased time afforded to mathematics in first year of secondary school in Ireland in comparison to sixth class impedes the continuity necessary for a successful transition.

Collaboration across the transition

Meaningful collaboration is necessary between sixth class and first year teachers. A greater awareness is needed of the curricula and teaching methodologies employed by each. Developing familiarity of the respective curricula and teaching methodologies should be a major concern of teacher educators at both levels and should be dealt with in teacher education programmes in primary and secondary education. The Communities of Practice model (Wenger 2000) emphasises the importance of parental involvement in the transition process. It also stresses the need for collaboration of parents, students and teachers to ensure student engagement and mastery. There is a statistically significant positive correlation between parents' attitudes towards mathematics and their children's attitude towards mathematics (Mohr-Schroeder et al. 2017) and parents' interest in the school and parents' level of satisfaction in mathematics is linked to students' belief in their own ability (Surgenor et al. 2006). Parents need to be given the tools to play a greater role in the mathematics education of their children in first year of secondary education to ensure transitional success. This is supported by the theoretical framework of both Schlossberg (1981) and Wenger (2000).

Effectiveness of the Common Introductory Course (CIC)

The academic results of this study question the effectiveness of the Common Introductory Course followed by first year students. The decrease in computational skills points to a need for increased practice and a possible over-reliance on the calculator. This decline in computation is only evident because students were not allowed to use a calculator on either the test at the end of sixth class or the test at the end of first year in this study. Both student motivation and learning can be improved by a moderate level of challenge (Brophy 2013; Stipek 1993). While continuity is a key factor in successful transition, continuity for first year students should not constitute a repetition of prior learning. The importance of student exposure to challenge in mathematics has been acknowledged by international research (Applebaum and Leikin 2007; Taylor 2005; Turner 2010), and yet many of the learning outcomes of

the Common Introductory Course are exactly the same as the learning outcomes for the sixth class mathematics syllabus. Therefore, it is hard to see how students can be sufficiently challenged under these circumstances by providing them with sufficient opportunities to develop understanding and reasoning skills.

In its present form, the Common Introductory Course undervalues the importance of building on student prior knowledge because a student's prior knowledge is not accessed as this course effectively assumes a fresh start approach where students are re-taught the material from sixth class. The fresh start approach in first year which disregards prior learning has been shown to have negative consequences for student engagement and learning (Bicknell and Hunter 2012; Galton et al. 2003). Diezmann and Watters (2002) posit that challenge is fundamental to progress in mathematics education. There is limited cognitive value to activities or problems that are too easy or too hard (Diezmann and Watters 2002). Motivation, interest and commitment or perseverance are all highly dependent on the provision of challenging tasks in the mathematics classroom (Diezmann and Watters 2002; Turner and Meyer 2004). Challenge in mathematics fosters qualities such as patience, perseverance and flexibility. It also allows students to enhance their mathematical understanding, develop their confidence and potential and ultimately allow for the experience of success and engagement with fellow learners (Barbeau and Taylor 2009).

Contribution

This study is important because it contributes to the discourse on transition and adds new evidence-based knowledge to the area, albeit in the academic area of school mathematics. Whereas there exists an extensive research literature on transitions in general and from primary to post-primary (secondary education) from sociocultural and psychological perspectives, the specific issues surrounding academic transitions are under-researched. The authors address this gap in the research by investigating student performance in mathematics after the transition from primary to secondary education in Ireland. Their study is underpinned by a theoretical framework that: integrates features of collaboration of parents, students and teachers; emphasises that adaptation to transition takes time; and uses the characteristics of the individual and the environment to explain and understand issues related to academic performance of students in mathematics.

The research intention and the design of the study are national in scope as they were directed at the Irish education system as a whole. While the problematic nature of the mathematics transition from primary school to post-primary school was acknowledged in official circles and by stakeholders, these concerns were not well established in research. Nevertheless, there was a significant effort to address the mathematics transition in the implementation of reform mathematics curriculum using a Common Introductory Course (CIC). The study uncovered unexpected shortcomings with the CIC programme and surprising levels of mathematical underperformance of students. The investigation established measures of underperformance and demonstrated that this underperformance was evident across all strands and not just in computation as reported in a previous study

(Smyth et al. 2004). Contributory issues such as instruction time, lack of effective collaboration between primary and post-primary teachers (mathematics), and the ‘fresh start approach’ adopted by post-primary mathematics teachers have been highlighted by this research. The evidence developed through this research is available for policy makers, school leaders and teachers, and mathematics teacher educators as they grapple with the task of improving school mathematics education for all or students.

It is expected colleagues in the wider international mathematics education research community will be interested in this study, its findings and what it tells us about addressing a mathematical transition in the context of a major national reform of the national curriculum in mathematics. More specifically, the study addresses a gap in the international literature on transition studies by focussing on the mathematical transition from primary to post-primary (secondary) school mathematics in Ireland in the context of major national reform of the mathematics curriculum; provides concrete data for comparisons with other similar studies in other countries; and provides opportunities for further learning by researchers and practitioners in the field. We can learn from successes and failures but also by studying serious attempts which fall short of the mark but are not yet failures because the whole story has not yet been enacted in the ongoing reform context.

Concluding remarks

This study is the first Irish study to provide a detailed analysis of academic achievement in mathematics over the transition period. Unlike Smyth’s study (Smyth et al. 2004), this study allowed for losses during the summer break by taking results at the end of sixth class and comparing them to results at the end of first year; used a large stratified random sample; and measured achievement by strand area and process skill. The results of this study show that the Common Introductory Course is not working as the levels of regression and standstill in mathematics during the primary to post-primary transition are far higher than our international counterparts. In addition, this failure is connected to the first-year teachers’ knowledge of the curriculum and teaching methodologies employed at primary level. The effectiveness of the Common Introductory Course in mathematics, designed to assist in the transition and followed by all students in their first year of education in post-primary school in Ireland, seems to be falling well short of its goals. As implemented, it represents much repetition of work already completed in sixth class and foregoes the opportunity to build on primary school mathematics.

The findings have major implications not only for our education system, but the personal development of young students, their present and future functioning within society, their career choices and the nation’s economic prosperity. Therefore, it is very important that we address student underperformance in mathematics in first year of post-primary school. Understanding what is happening at this time in students’ lives is necessary if we want to raise student levels of knowledge and understanding in mathematics, both nationally and internationally.

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Data availability The datasets generated during and analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Ethical approval Ethical approval for this study was granted by the appropriate ethics committee at the University of Limerick (Code: 2015_09_01_S&E). The parents, students, teachers and individuals involved in the study were informed of the purpose of the research in advance of data collection and they had the opportunity to withdraw from the study throughout the process. Approval was granted by the parents, school principals and the University of Limerick. Parental consent was secured for all participating students. In addition, school principals from both primary and post-primary schools were asked to consent to the research on behalf of their staff and students. Once overall consent was agreed, individual staff and students were sent a letter of consent. As part of the process of gaining their informed voluntary consent, the purpose and methodology of the study was explained to all participants. Each student was allocated a number to guarantee confidentiality. In June 2015, a letter of consent was sent to all parents, teachers and principals involved explaining their role and that of the students involved in the study. Leaflets containing relevant information explaining the research purposes and procedures were also provided to students and their parents/guardians to inform their decision regarding whether to agree to participate.

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